Mirt with integrated chimney

Institutional Mirt

STOVE TESTING RESULTS

A Report on Controlled Cooking Test Results Performed on 'Mirt with integrated chimney' and 'Institutional Mirt' Stoves

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Stove Testing Results

Following is presented the results of testing carried out on stoves- Mirt with integrated chimney and Institutional Mirt. Several Controlled cooking tests (CCT) were carried out between 9 and 20 May 2011.

1. The stoves

1.1 Mirt with integrated chimney

Mirt with integrated chimney, as the name suggests, is basically mirt and a chimney is attached to it. Its advantage is that the chimney allows for total removal of smoke from the kitchen where the stove is to be installed without necessarily sacrificing the advantage of ordinary mirt, which is using the smoke for cooking purpose while baking injera. Below is presented a description of ordinary mirt as it is the basic stove. Latter, how the chimney is integrated to the basic stove is described.

Mirt is one of the stoves GIZ-ECO is promoting (see Figs. 1 and 2). It is made out of mortar (a mixture of scoria and cement) primarily designed for baking injera. But additionally has a provision for carrying out other cooking tasks such as *wot* (sauce) making or boiling. The stove is basically cylindrically shaped enclosure whose axis is vertically oriented. With an opening around the bottom (fire-bed level) of its lateral face as air-fuel inlet and another of smaller size as exhaust outlet opposite but above the level of the fire-bed, this cylindrical enclosure is made when four mating pieces fit together. These four parts (quadrants) constitute the wall of the stove inside of which is where combustion of fuel takes place. The walls at their top rim provide for resting the ceramic plate (called *mitad*) on which injera is baked. Inside, at the bottom of the enclosure is just the fire-bed where burning fuel (firewood, agri-residue, leaves or branches) dwells in the stove.

At the back where the smoke exits are placed two other parts (‘O’ and ‘U’- chimney stack), one atop the other, augmented with the cylindrical enclosure. These parts manage the exhaust of the stove system by causing regulated flow and even more advantageously for using the exhaust as a source of energy for cooking in addition to the baking activity. One of these, the U-shaped structure, whose void at its inside makes the exhaust to slow its speed so that combustion is optimal in the combustion chamber. Further, it supports the ‘O’ part of the stove resting on it from above.

The ‘O’ serves firstly the purpose of creating draft for the stove by virtue of creating sufficient level difference between itself and that of the fire-bed. Secondly, its opening allows enough amount of smoke to touch against the bottom of a pot sitting on three risers built on it. This is where the added advantage of mirt is realized-cooking on pot in addition to the main purpose of baking injera.

Currently, mirt is appearing in two varieties on the market: classic- and slim-mirt. Their difference is mainly on the wall thicknesses of their respective parts. Classic mirt has its quadrant parts as well as its ‘U’ chimney stack, a wall thickness of all 6cm. Where as the corresponding size for slim mirt is 4cm. Another, rather less important, difference is that

classic mirt has a step like shoulder that secures *mitad* in position on its quadrant parts. This is absent on slim mirt because it is difficult to make such a shape on the relatively thinner wall.

Figure 1 Mirt Stove with baking plate and cover

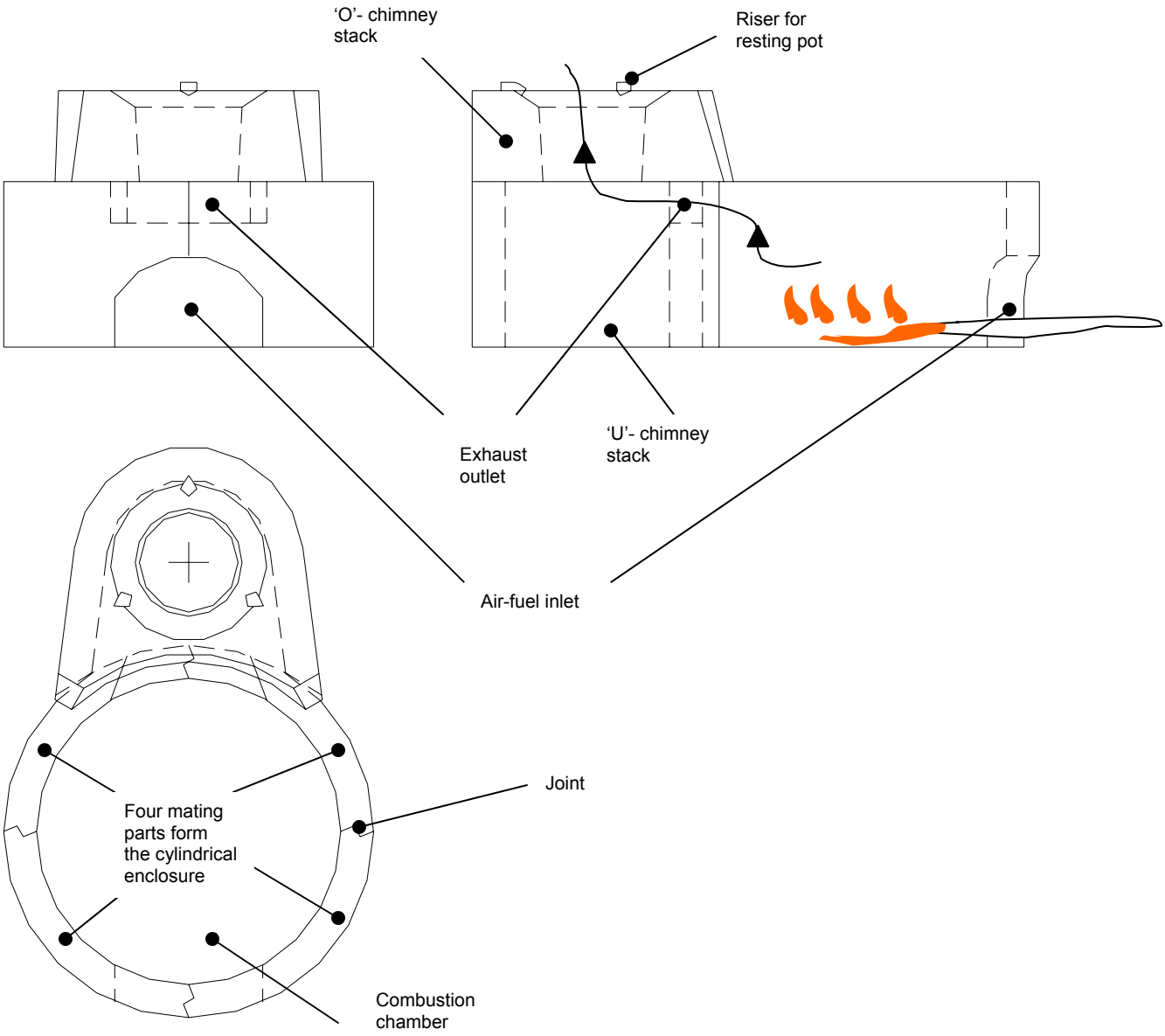

Figure 2 Orthographic views of mirt stove (not to scale)

The development of slim mirt was necessary due to the ever rising of the cost of raw materials of the production of mirt which has eventually a bearing on the price of the stove and hence its dissemination. The mitigation measure to this problem was reducing the amount of raw material necessary to produce the stove so that the cost of production could be cut. This was important as, especially, households tend to be sensitive to the price of the stove for its adoption. Compared to the classic, slim mirt requires 40 to 50% less amount of raw material for its production. This has a potential to cut the price of the stove substantially. In a specific town, for example, the price of slim was 70Birr compared to 110Birr of classic in April 2011. This is more than 35% reduction.

Generally, now slim mirt is adopted by households and classic mirt is adopted by consumers which bake injera more frequently and in greater quantities (e.g. commercial injera bakers, institutional users, etc.).

Figure 3 shows a schematic of mirt with integrated chimney. It can be seen that the stove is all mirt with a chimney that takes all the smoke out of the room where the stove is installed. The chimney, made of sheet metal of 0.8mm thickness, has cross section about 10cm by 10cm if it is square or 10cm in diameter if it is circular. And it is expected to be between 80 and 100cm[1] in height, relative to the fire-bed level of the stove. This is for optimal generation of draft. Optimal draft is important since it affects the efficiency of the stove, clean combustion of fuel and the proper smoke removal from the system.

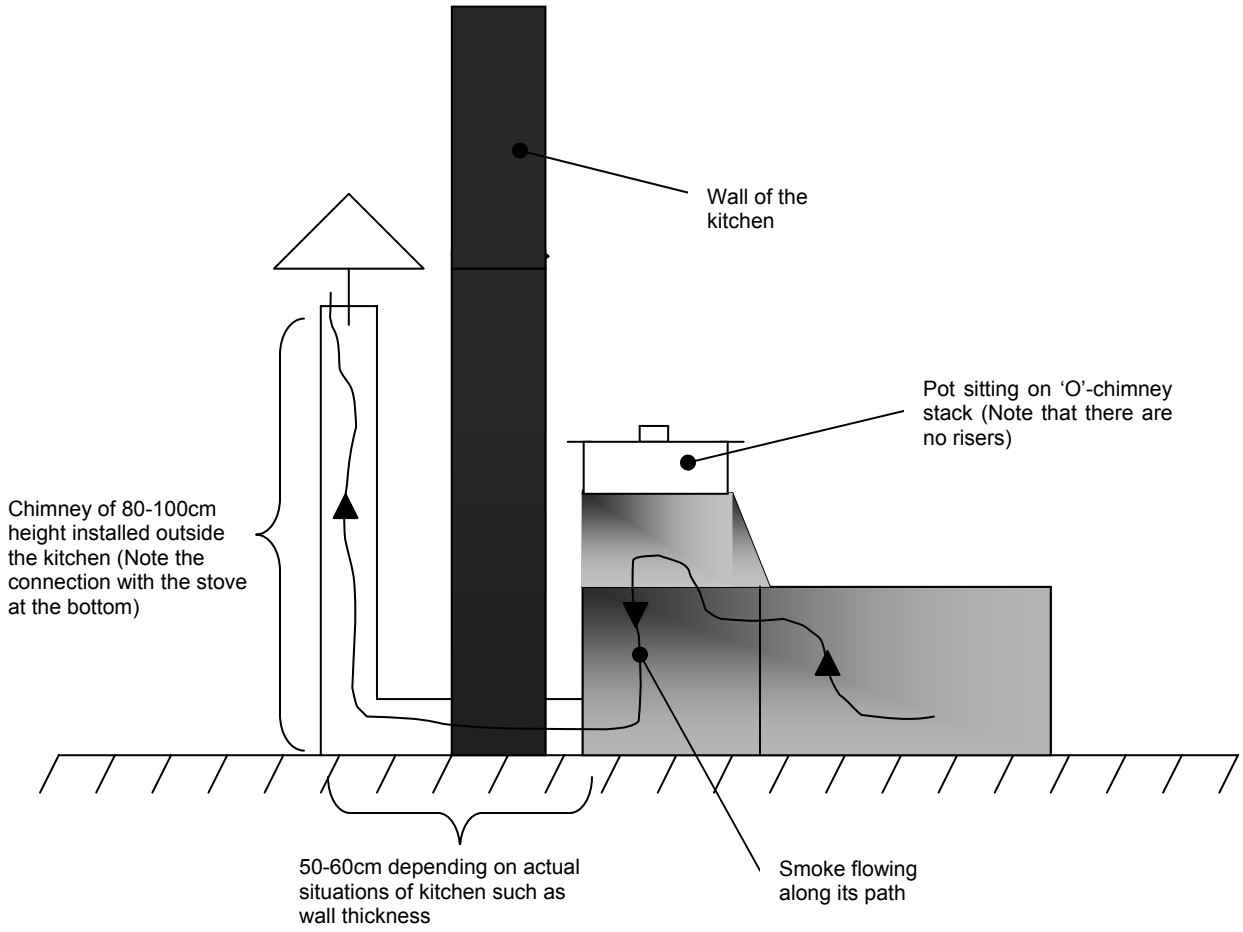

Figure 3 Schematic of a hypothetical mirt with integrated chimney (not to scale)

[1] For this particular test the actual height used was 1.45m. But from the couples of trials carried out, it seemed 80-100cm would be a good height range for optimal performance of the stove.

1.2 Institutional Mirt

Institutional mirt, in this context, is a name given to (classic) mirt installations where four of these stoves are installed adjacent to one another (but not in cascade) such that smoke from all of them is channeled through one chimney off the kitchen where they are installed. A unit called chimney-support is produced from the same material (i.e. mortar) and rests on all of the four individual stoves and it guides smoke through the chimney. The chimney then rises up outside the roof of the kitchen. The circularly cross-sectioned chimney is 20cm in diameter and is usually 3-5m high[2]. Great quantities of injera baking depending on the specific application means that the stove is used for extended period per day and the chimney undergoes high temperature operation. This entails radiative heat coming off the chimney to the injera bakers causing them inconvenience. To address this problem at least the one meter height of the chimney is made to be covered with insulation that reduces the temperature at heights close to the bakers.

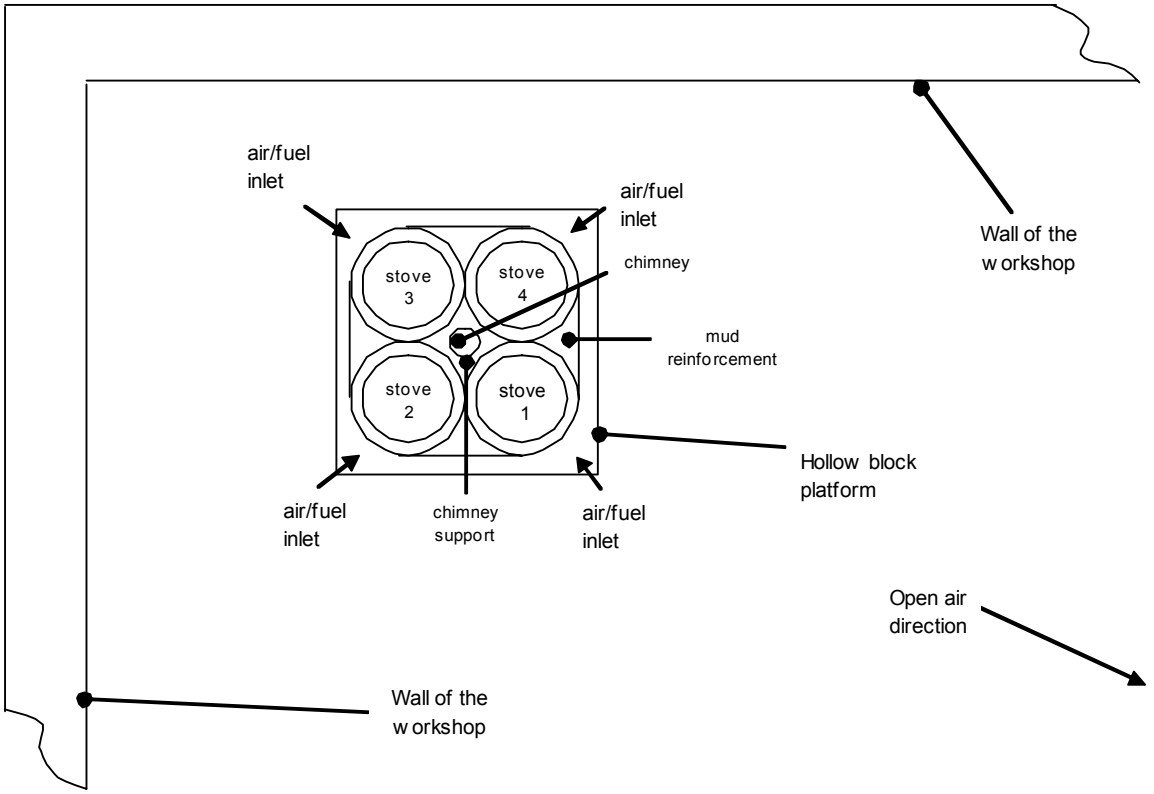

Figure 4 Plan view schematic of Institutional Mirt installed in the testing room (not to scale)

Regarding the bakers necessary for a stove set, a cluster of four individual stoves does not mean that four bakers are needed. It all depends on the ability of the bakers handling the tasks efficiently but a baker can handle at least two individual stoves at a time. There is a report of a baker handling four stoves in a row.

[2] The stove on which the tests were conducted had 3meters high chimney.

2. Test procedure

Controlled cooking test (CCT), according to the protocol of the University of California-Berkeley (UCB), is employed here in the test. The corresponding data entry and calculation spreadsheets were utilized. The goal of such test is basically to get the value of *specific fuel consumption* of a stove, which is the amount of fuel used to produce a unit amount of food expressed in units of g/kg. This is the main parameter used for comparing the improved stove against the baseline stove. The total time of producing a certain amount of food is also a measure of stove performance. Therefore total time of production of injera was recorded for each of the baking sessions.

To see how long it would take the stoves before they would allow baking the first injera, during some of the tests, time was also recorded when the first pouring of dough on the mitad was done. Whenever possible, injera production time for each baking cycle (i.e. for baking one injera) was recorded as well.

Other observations such as the users' perception on the stoves in general on the whole baking practice had also been noted. A systematic record was not done but temperatures on different spots of the mitad before and after each injera baking as well as during the initial heating of the mitad were monitored.

Following the protocol, at least three rounds of test are required and that was done accordingly. Whenever a test shows inconsistent result with others, it was re-done. And design modifications (such as chimney height increase or reduction) may necessitate more tests as well.

The following quantities were recorded during the tests:

- Mass of firewood (before and after each test)
- Moisture of firewood
- Time the stove was lit (when the fire catches)
- Time when the first pouring of dough took place (not for all the tests)
- Time the test ends (normally is the time when the last injera is removed off the mitad)
- Mass of charcoal remaining
- Mass of injera baked
- Number of injera baked
- Mass of dough used to bake injera
- Time to bake each injera (not for all the tests)
- Time to heat the mitad before the next injera was going to be baked (not for all the tests)

On both stoves the common practice of baking injera in a common household, which is producing 25-30 injeras per stove per session utilizing close to 16kgs of dough was applied. Generally the numbers of injera falls in the aforementioned range. But the actual number depends on how viscous the dough is and how thin the injera is. These in turn depend on the individual who prepares the dough and doing the baking, respectively. The

range of the numbers of injera is, anyway, what a typical Ethiopian household would bake per session.

For the institutional stove this quantity is certainly not to be expected in real life. But for comparison purpose we have to do it that way since the baseline stove (three-stone open fire) against which we compare our stove is tested only with the said amount of injera since we don't have a typical quantity that represents institutions.

3. Testing materials, equipment and apparatus

The following test materials, equipment and facilities were used during the tests:

- Electronic weighing balance-1
- Fuel moisture meter-1
- Digital thermometer-1
- Thermocouple-1
- IR thermometer-1
- Tongs for charcoal removal-1
- Charcoal container-1
- Hand gloves-1 pair
- Complete stove installation-1
- Injera container-1
- Dough with container-16kg net dough per session per stove
- Firewood- 12kg per session on average
- Other utilities and accessories (seasoning seed, water with container, dough pouring jug, small water bath)
-

4. Results

4.1 Mirt with integrated chimney

Table 1 shows summary of test results for mirt with integrated chimney. Note that no test was done for open fire (baseline stove) now for this investigation but was done previously and for which a report is available. Comparisons are therefore based on this report for the baseline stove.

Table 1 CCT results of Mirt with integrated chimney

CCT results: Mirt with integrated chimney	Units	Test 1	Test 2	Test 3	Mean	St Dev	CoV
Total weight of food cooked	g	11030	11250	10930	11070	163.7	1.5%
Weight of char remaining	g	930	990	1110	1010	91.7	9.1%
Equivalent dry wood consumed	g	6481	6382	6924	6596	288.4	4.4%
Specific fuel consumption	g/kg	588	567	633	**596**	33.9	5.7%
Total cooking time	min	101	98	107	**102**	4.6	4.5%

As can be seen from the table, the average specific fuel consumption of the stove is 596g/kg. The average total time used for baking injera using the standard amount of 16kg dough has been found to be 102minutes. Comparing these with the corresponding figures

for open fire (which are 1031g/kg and 121minutes[3] respectively) reductions of 42% and 15%, respectively, for fuel and time have been attained. These are certainly eye-catching numbers since usually chimneying a stove and maintaining its fuel efficiency do not go together.

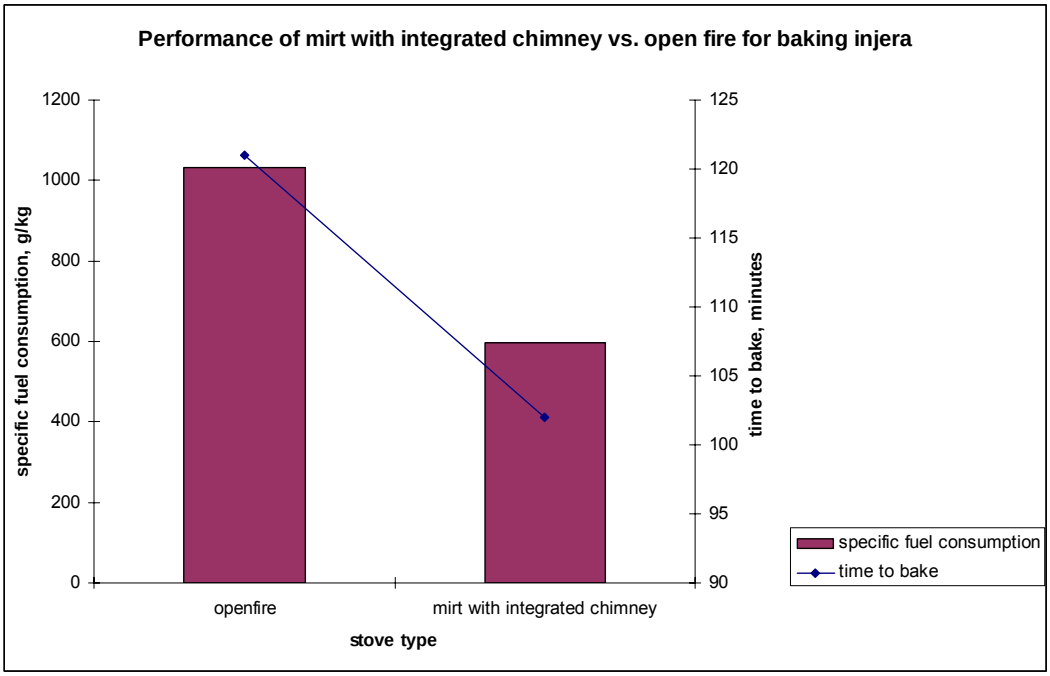

Figure 5 Performance of mirt with integrated chimney vs. open fire for baking injera

In addition to the 'start' and 'end' of each baking test for the total session, for some of the tests 'dough poured' and 'injera removed' time data were registered to determine the cycle time for baking one injera. All the data from the tests are tabulated in annex 6.1. As could be seen from the tables an average 'baking time' per injera of 2.3minutes and of mitad 'reheating time' of 0.7 minute have been recorded. These sum to an average cycle time per injera of 3minutes. Since records of such times were not documented it is difficult to compare with any baseline but it is the author's experience that this figure is smaller than for the three-stone open fire stove. Especially the mitad 'reheating time' is so small that the major gain in total time saving for the whole session might be mainly attributed to the gain in this time.

Table 2 Time to bake per cycle of baking one injera

	minutes to bake per cycle	
	to bake	to reheat
CCT 1	2.44	0.7
CCT 2	2.24	0.6
CCT 3	2.24	0.9
mean	2.3	0.7

[3] Source: "Stove testing result memo", Hiwote Teshome, GTZ-SUN Energy.

Another performance indicator is the time between the firing of the stove and first injera baking. This was not however recorded for all of the tests but, it looks like a saving might have been achieved in this time as well. Again from experience, such time is about 30minutes for open-fire and even for ordinary mirt stove. But, for example the corresponding times during CCT 1 and CCT 2 for mirt with integrated chimney were just 14minutes and 16minutes, respectively. Again this time saving should also be responsible for the overall time saving for this stove over the baseline.

Finally, on the perception of the injera bakers on the stove is that no complaint what so ever was forwarded. One thing to mention here though is that during one of the tests, the baker was noted to try to cool the baking plate (mitad) using water around the smoke outlet from the combustion chamber. This is not so abnormal and it is sometimes observed some stove producers doing it. An explanation could be the fast moving smoke leaving the system under turbulent conditions causes more heat to transfer to the mitad resulting in higher temperatures. A mitigation option could thus be, to reduce the speed of the exhaust which could be achieved through baffling or reducing the height of the chimney to reduce the draft.

4.2 Institutional Mirt

The test results of CCT on institutional mirt are summarized as in table 3 below. Since the stove as one system is composed of four individual mirt stoves, the relevant figure of specific fuel consumption is obtained by averaging the corresponding figures of each of the stoves- it is 528g/kg. Similarly, a total baking time of 101minutes on average was obtained. These mean reductions in fuel and time consumptions compared to open fire, respectively, of 49% and 16%. Again these are quite numbers that are not usually expected with a stove having a chimney.

Table 3 CCT results of institutional mirt

		stove 1	stove 2	stove 3	stove 4	mean	Std dev	CoV	Open fire	Saving over open fire
Total weight of food cooked	g	10990	11237	11633	11630	11373	316	2.8%		
Weight of char remaining	g	370	400	730	637	534	177	33.1%		
Equivalent dry wood consumed	g	5828	5628	6578	5986	6005	409	6.8%		
Specific fuel consumption	g/kg	531	501	565	515	528	28	5.3%	1031	48.8%
Total cooking time	min	105	110	95	95	101	8	7.6%	121	16.5%

Regarding the feedback from the bakers on the stove, both of them said they liked the stove. It is important to note that one of them did not have experience on mirt stove at all but the whole baking went well without any significant problem. One thing that must be noted here though is that on the stoves where this new baker baked (stoves 3&4), the

remaining char appeared to be more compared to the other two. There could be other factors but it is most likely associated with the baker itself. The other possible factor would be wind (or too much air entering the system). But from the test set-up this does not seem to be the case because, first the draft is the same for all stoves in the cluster. Secondly, for the wind, there was no wind during the execution of the tests and even if there were, these particular stoves (3&4) would be protected from it more than stoves 1&2 (see fig. 4).

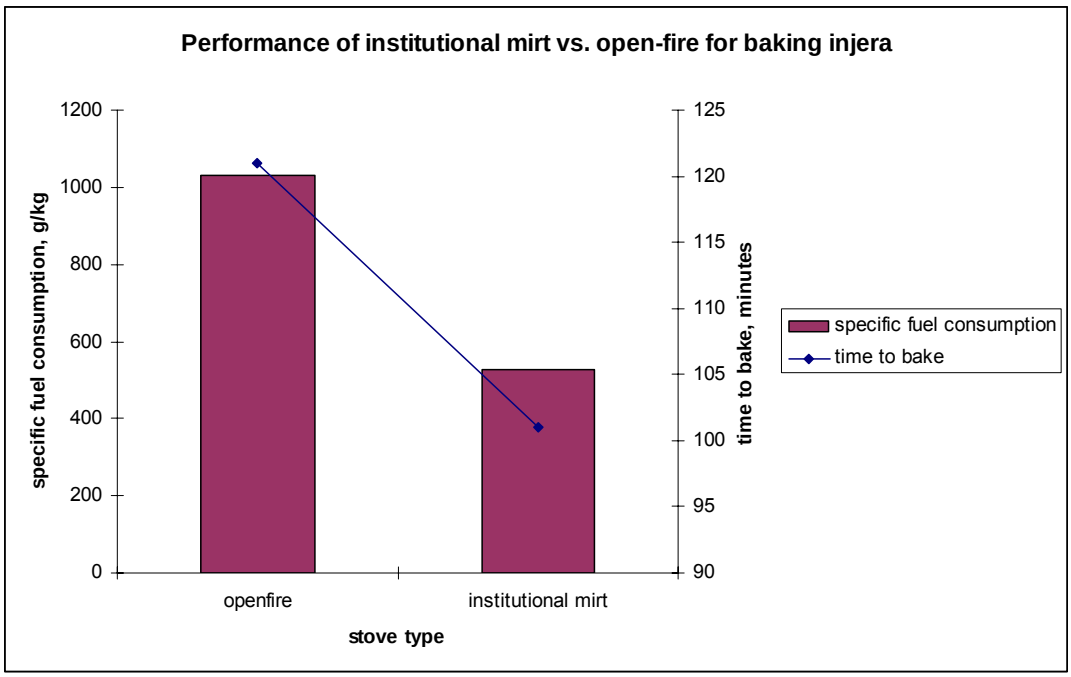

Figure 6 Performance of institutional mirt vs. open-fire for injera baking

5. Conclusions and Recommendations

As discussed earlier, the tests show encouraging results. At the outset, the particular stove designs (both mirt with integrated chimney and institutional mirt) are considered because of certain specific needs. The following sections discuss each stove separately.

5.1 Mirt with integrated chimney

Challenge is looming for mirt as it is more and more becoming necessary to improve indoor air quality in households. Improved stoves such as mirt have great potential in achieving that (because of improved combustion efficiency and total reduction in burning fuel) but nevertheless 100% (or close to that) removal of smoke out of kitchens has not so far been achieved. This has been particularly seen as a problem in certain areas of the project where such requirements are strictly to be met. Tigray and Amhara regions are the case in point and this has saw ignorance, by the local health extension experts, to the stove and in extreme cases, replacement of the stove with chimneyed mud stoves which are not necessarily better in terms of fuel saving or other advantages.

The integration of chimney with mirt should address this problem. As opposed to the previous attempts, with the current design the additional advantage of mirt to allow pot-based cooking is maintained. Currently the trade-off is between smoke removal (e.g. in what they call *lakech*[4] injera stove) and using the heat of smoke for cooking (e.g. in mirt stove). But with mirt with integrated chimney there is no this trade-off, both advantages are maintained.

The disadvantage of mirt with integrated chimney tested here, however, is the additional cost of chimney. In addition, installation of the stove for new adopters or the chimney for existing mirt users may be even more complicated. Although not so frequent, regular cleaning of the chimney may also be additional work for the users. But these could be addressed through intensive awareness creation measures, collaborations with local energy and health departments and employing appropriate financing mechanisms.

The setback posed on mirt by the folks who are unfavorably treating it (the health extension workers) could now be used positively to disseminate the new stove, because, 'smokeless' stove is now made available to them. If this opportunity is utilized well, the under-privileged energy sector, which has long suffered ignorance, would have a new strong partner.

To address cost issues, carbon financing could be considered an instrument. The project does not have experience in this but the additional cost of the chimney would be an incentive to pursue such mechanism. But for the near term, micro-crediting schemes may also be considered.

Finally, intensive awareness creation is an indispensible tool to influence all stakeholders at all levels including, stove producers, users, sector and other public institutions and development agencies.

While promotion of the stove continues, it is also necessary to investigate other options in the design of the stove itself. The chimney could be, for example, tested with lesser (than the tested 145cm) height and constructed from cheaper raw material such as mud. Another design feature that could potentially be interesting for cities like Addis Ababa is to produce the stove with metal cladding and support structure so that it is absolutely portable stove.

5.2 Institutional Mirt

When averaged, for each of the stoves in the cluster, the value of specific fuel consumption for institutional mirt is nearly the same for ordinary mirt. This, although not expected, is a good result. The introduction of chimney to a stove introduces additional draft that sucks more air into the system which, when more than required, disrupts

[4] The name '*Lakech*' is mistakenly used by the public for modified mirt stove with cladding and having metallic support structure. It was intended first, by the then Ethiopian Rural Energy Development and Promotion Center (EREDPC), for institutional users but has been now widely adopted especially by urban households. The legitimate stove to have the name '*Lakech*' is the improved charcoal stove developed by the same institution-EREDPC.

combustion and thus overall efficiency. The additional air also robs off heat from the system rendering the stove even less efficient.

One of the reasons for the counter intuitive result may be the application of mud around the stove body. The mud is mixed with straw and is therefore lighter than pure mud. This adds more to the insulation than it does to the mass of the stove.

Another reason might be the configuration of the individual stoves within the stove as a stove wholly. Since its exposed body surface as a whole to the ambient, compared to a single mirt stove, is substantially reduced the stove gets heated quicker because of improved insulation.

A single test was performed first using less amount of dough (13.5kg). The performance of the stove was poor unlike the results reported here for that particular test. A possible explanation here might be the number of injeras baked, which was smaller. This phenomenon lends itself for a need for investigation of the performance of the stove for different numbers of injera. The hypothesis though is that because of the heat inertia the stove becomes more efficient when more injeras are baked which is the prevalent situation of baking in institutions.

Finally, a note on the stove design is that the four-tipped star shaped structure for chimney supporting has a mechanical stress problem. Although not always, it cracks in the areas where it receives smoke from the combustion zone. The problem appears to come from the shape of the structure itself and from high differential temperature exposure in these areas. To come around this problem, a candidate solution worth trying could be switching the construction material from mortar to clay.

Another problem noted from previous installations was that in the same areas of the chimney support structure the part was seen to be eroded by the fast flowing smoke. As a remedy to this, angle-iron protection along the curved shape part were installed and reported to work well.

Institutional mirt stoves have been installed in a couple of institutions so far. The result obtained here shall be an extra tool to be used to pursue their wide spread promotion to more institutions.

6. Annexes

6.1 Test results

Table 4 CCT 1 for mirt with integrated chimney

CCT-1 for the **Slim Mirt with integrated Chimney**

Wind conditions: no wind (2 1)

Air temperature: **20.8** ºC

Shaded cells require user input; unshaded cells automatically display outputs

To be filled in after cooking task is complete (as defined by the directions on the "Description" worksheet)

MEASUREMENTS	Units	Initial measurements data	Initial measurements label	Final measurements data	Final measurements label	
Weight of wood used for cooking	g	13060	f_i	4110	f_f	inkib (pot) wt: 650gm; empty bucket wt: 1110gm
Weight of charcoal+container	g			1370	c_c	charcoal container wt: 440gm; net dough wt: 16000gm
Weight of Pot # 1 with cooked food	g			11670	$P1_f$	first pouring of dough: 9:53a.m.
Weight of Pot # 2 with cooked food	g				$P2_f$	bucket with remaining dough wt: 1720gm
Weight of Pot # 3 with cooked food	g				$P3_f$	total number of injera baked: 29
Weight of Pot # 4 with cooked food	g				$P4_f$	remaining charcoal with container: 710+780+760gm
Time	min	0	t_i	101	t_f	this test was conducted on 12.05.2011

CALCULATIONS	Units		Formula	CALCULATIONS	Units		Formula
Total weight of food cooked	g	11030	$W_f = \sum_{j=1}^{4}(Pj_f - Pj)$	Specific fuel consumption	g/kg	588	$SC = \frac{f_d}{W_f} * 1000$
Weight of char remaining	g	930	$\Delta c_c = k - c_c$	Total cooking time	min	101	$\Delta t = t_f - t_i$
Equivalent dry wood consumed	g	6481	$f_d = (f_f - f_i) * (1 - (1.12 * m)) - 1.5 * \Delta c_c$				

Table 5 CCT 2 for mirt with integrated chimney

CCT-2 for the	**Slim Mirt with integerated Chimney**					Wind conditions	no wind / 2	
Shaded cells require user input; unshaded cells automatically display outputs						Air temperature	**21.5**	ºC

To be filled in after cooking task is complete (as defined by the directions on the "Description" worksheet)

MEASUREMENTS	Units	Initial measurements data	Initial measurements label	Final measurements data	Final measurements label	
Weight of wood used for cooking	g	12180	f_i	3240	f_f	pot wt: 640g; chimney height: 145cm from firebed level
Weight of charcoal+container	g			1430	c_c	char container wt: 440g; dough container wt.: 1110g
Weight of Pot # 1 with cooked food	g			11890	$P1_f$	dough wt.: 16000g: dimension of wood: 85x3x2cm
Weight of Pot # 2 with cooked food	g				$P2_f$	first pouring of dough at: 10:27am; total # injera baked: 27;
Weight of Pot # 3 with cooked food	g				$P3_f$	more than 3.5liters of water was made to boil and this was achieved in about 1hour time after the stove was first lit.
Weight of Pot # 4 with cooked food	g				$P4_f$	this test was conducted on 10.05.2011.
Time	min		t_i	98	t_f	

CALCULATIONS			Formula	CALCULATIONS			Formula
Total weight of food cooked	g	11250	$W_f = \sum_{j=1}^{4}(Pj_f - Pj)$	Specific fuel consumption	g/kg	567	$SC = \frac{f_d}{W_f} * 1000$
Weight of char remaining	g	990	$\Delta c_c = k - c_c$	Total cooking time	min	98	$\Delta t = t_f - t_i$
Equivalent dry wood consumed	g	6382	$f_d = (f_f - f_i) * (1 - (1.12 * m)) - 1.5 * \Delta c_c$				

Table 6 CCT 2 for mirt with integrated chimney

CCT-3 for the	**Slim Mirt with integrated Chimney**						Wind conditions	no wind / 2	
							Air temperature	**21.9**	ºC

Shaded cells require user input; unshaded cells automatically display outputs

To be filled in after cooking task is complete (as defined by the directions on the "Description" worksheet)

MEASUREMENTS	Units	Initial measurements data	Initial measurements label	Final measurements data	Final measurements label	
Weight of wood used for cooking	g	15630	f_i	5870	f_f	empty dough container wt.: 1110gm; net dough wt: 16000gm
Weight of charcoal+container	g			1550	c_c	empty charcoal container wt.: 440gm; pot (inkib) wt: 650gm
Weight of Pot # 1 with cooked food	g			11570	$P1_f$	dough temperature:28.5
Weight of Pot # 2 with cooked food	g				$P2_f$	remaining dough with container wt:1420gm
Weight of Pot # 3 with cooked food	g				$P3_f$	total # injera baked: 30
Weight of Pot # 4 with cooked food	g				$P4_f$	this test was conducted on 13.05.2011
Time	min		t_i	107	t_f	4litres of water was made to boil in about 1:22hr after stove was first lit.

CALCULATIONS			Formula	CALCULATIONS			Formula
Total weight of food cooked	g	10930	$W_f = \sum_{j=1}^{4}(Pj_f - Pj)$	Specific fuel consumption	g/kg	633	$SC = \frac{f_d}{W_f} * 1000$
Weight of char remaining	g	1110	$\Delta c_c = k - c_c$	Total cooking time	min	107	$\Delta t = t_f - t_i$
Equivalent dry wood consumed	g	6924	$f_d = (f_f - f_i) * (1 - (1.12 * m)) - 1.5 * \Delta c_c$				

Table 7 Time to bake per cycle CCT 1

date:
10.05.2011

			time to bake		time to reheat	
time dough poured	time injera removed			minutes		minutes
10:27	10:31	00:04	4		00:01	1
10:32	10:35	00:03	3		00:01	1
10:36	10:39	00:03	3		00:01	1
10:40	10:43	00:03	3		-	discontinuity
10:51	10:53	00:02	2		00:01	1
10:54	10:56	00:02	2		00:01	1
10:57	10:59	00:02	2		00:01	1
11:00	11:02	00:02	2		00:00	0
11:02	11:05	00:03	3		00:00	0
11:05	11:08	00:03	3		00:00	0
11:08	11:10	00:02	2		00:01	1
11:11	11:13	00:02	2		00:01	1
11:14	11:16	00:02	2		00:01	1
11:17	11:19	00:02	2		00:00	0
11:19	11:22	00:03	3		00:01	1
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11:25	11:28	00:03	3		00:00	0
11:28	11:30	00:02	2		00:01	1
11:31	11:33	00:02	2		00:01	1
11:34	11:36	00:02	2		00:01	1
11:37	11:39	00:02	2		00:01	1
11:40	11:42	00:02	2		00:01	1
11:43	11:45	00:02	2		00:00	0
11:45	11:48	00:03	3		00:00	0
11:48	11:51	00:03	3		-	
	average	0:02	2.44		0:00	0.7

Table 8 Time to bake per cycle CCT 2

date:
12.05.2011

			time to bake		time to reheat	
time dough poured	time injera removed			minutes		minutes
09:53	09:55	00:02	2		00:01	1
09:56	10:00	00:04	4		00:01	1
10:01	10:04	00:03	3		00:01	1
10:05	10:07	00:02	2		00:01	1
10:08	10:11	00:03	3		00:01	1
10:12	10:14	00:02	2		00:01	1
10:15	10:18	00:03	3		-	
10:20	10:22	00:02	2		00:01	1
10:23	10:24	00:01	1		00:01	1
10:25	10:28	00:03	3		00:00	0
10:28	10:30	00:02	2		00:01	1
10:31	10:33	00:02	2		00:01	1
10:34	10:36	00:02	2		00:00	0
10:36	10:38	00:02	2		00:02	2
10:40	10:42	00:02	2		00:01	1
10:43	10:45	00:02	2		00:00	0
10:45	10:47	00:02	2		00:01	1
10:48	10:50	00:02	2		00:00	0
10:50	10:53	00:03	3		00:00	0
10:53	10:55	00:02	2		00:00	0
10:55	10:58	00:03	3		00:00	0
10:58	11:00	00:02	2		00:01	1
11:01	11:03	00:02	2		00:01	1
11:04	11:06	00:02	2		00:00	0
11:06	11:08	00:02	2		00:01	1
11:09	11:11	00:02	2		00:00	0
11:11	11:13	00:02	2		00:01	1
11:14	11:16	00:02	2		00:00	0
11:16	11:18	00:02	2		-	0
	average	0:02	2.24		0:00	0.6

Table 9 Time to bake per cycle CCT 3

date:
13.05.2011

			time to bake		time to reheat	
time dough poured	time injera removed			minutes		minutes
10:23	10:25	00:02	2		00:01	1
10:26	10:29	00:03	3		00:01	1
10:30	10:33	00:03	3		00:01	1
10:34	10:36	00:02	2		00:02	2
10:38	10:41	00:03	3		-	
10:56	10:58	00:02	2		00:00	0
10:58	11:00	00:02	2		00:01	1
11:01	11:03	00:02	2		00:01	1
11:04	11:07	00:03	3		00:01	1
11:08	11:11	00:03	3		00:01	1
11:12	11:14	00:02	2		00:01	1
11:15	11:17	00:02	2		00:01	1
11:18	11:21	00:03	3		00:01	1
11:22	11:24	00:02	2		00:01	1
11:25	11:27	00:02	2		00:00	0
11:27	11:30	00:03	3		00:01	1
11:31	11:32	00:01	1		00:01	1
11:33	11:35	00:02	2		00:01	1
11:36	11:38	00:02	2		00:01	1
11:39	11:41	00:02	2		00:00	0
11:41	11:43	00:02	2		00:01	1
11:44	11:46	00:02	2		00:01	1
11:47	11:49	00:02	2		00:00	0
11:49	11:51	00:02	2		00:01	1
11:52	11:54	00:02	2		-	
	average	0:02	2.24		0:00	0.9

Table 10 Institutional Mirt CCT results

Institutional Mirt Testing

			stove 1	stove 2	stove 3	stove 4	average	Stdev	CoV	Open fire	Saving over open fire
Test 1 17.05.2011	Total weight of food cooked	g	10920	11110	11380	11730	11285	352	3.1%		
	Weight of char remaining	g	390	520	670	640	555	128	23.0%		
	Equivalent dry wood consumed	g	5585	5372	6534	6001	5873	512	8.7%		
	Specific fuel consumption	g/kg	511	484	574	512	520	38	7.4%	1031	49.0%
	Total cooking time	min	107	116	99	100	106	8	7.4%	121	12.08%

			stove 1	stove 2	stove 3	stove 4	average	Stdev	CoV	Open fire	Saving over open fire
Test 2 18.05.2011	Total weight of food cooked	g	11620	11490	11660	11440	11553	104	0.9%		
	Weight of char remaining	g	380	310	560	710	490	181	36.8%		
	Equivalent dry wood consumed	g	6035	5874	6041	5700	5913	161	2.7%		
	Specific fuel consumption	g/kg	519	511	518	498	512	10	1.9%	1031	50.4%
	Total cooking time	min	99	103	95	94	98	4	4.2%	121	19.2%

			stove 1	stove 2	stove 3	stove 4	average	Stdev	CoV	Open fire	Saving over open fire
Test 3 19.05.2011	Total weight of food cooked	g	10430	11110	11860	11720	11280	654	5.8%		
	Weight of char remaining	g	340	370	960	560	558	285	51.2%		
	Equivalent dry wood consumed	g	5864	5637	7159	6258	6229	670	10.8%		
	Specific fuel consumption	g/kg	562	507	604	534	552	41	7.5%	1031	46.5%
	Total cooking time	min	109	111	90	90	100	12	11.6%	121	17.4%

			stove 1	stove 2	stove 3	stove 4	average	Stdev	CoV	Open fire	Saving over open fire
Average of tests 1,2 and 3	Total weight of food cooked	g	10990	11237	11633	11630	11373	316	2.8%		
	Weight of char remaining	g	370	400	730	637	534	177	33.1%		
	Equivalent dry wood consumed	g	5828	5628	6578	5986	6005	409	6.8%		
	Specific fuel consumption	g/kg	531	501	565	515	528	28	5.3%	1031	48.8%
	Total cooking time	min	105	110	95	95	101	8	7.6%	121	16.5%

6.2 The testing in pictures

(a)

(b)

Figure 7 Mirt with integrated chimney

(a)

(b)

Figure 8 Institutional Mirt

6.3 Institutional Mirt installation

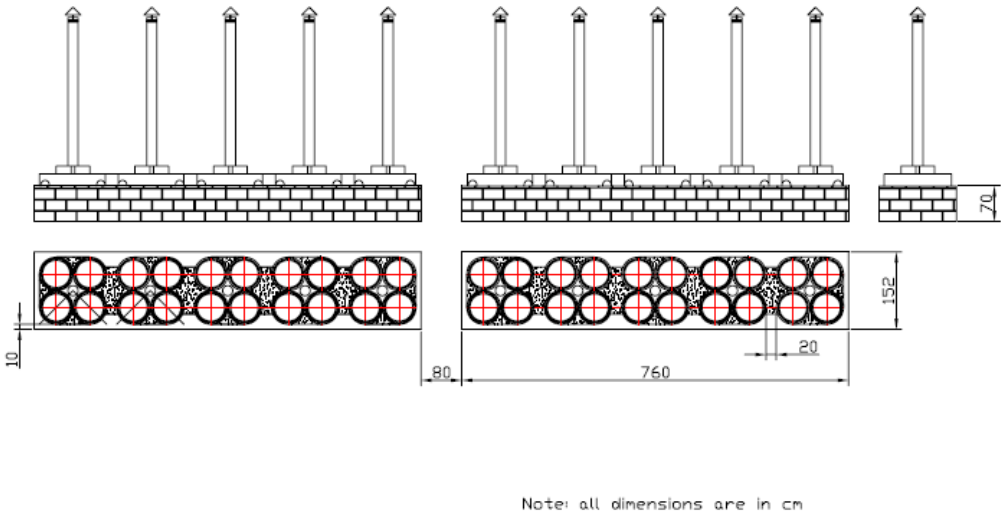

Figure 9 A typical institutional mirt installation (schematic)